

**TITLE OF THE INVENTION**

**Location System and Method for Operating Mobile Terminal as a  
Responsible Location for Selecting a Positioning Method**

**BACKGROUND OF THE INVENTION****Field of the Invention**

The present invention relates generally to location systems, and more specifically to a location system in which a number of positioning methods are selectively used depending on accuracy requested by a LCS (LoCation Service) client terminal.

**Description of the Related Art**

In the location system as standardized by 3GPP (3rd Generation Partnership Project) TS 25.305, a number of positioning methods are used, including Cell-ID method, OTDOA (Observed Time Difference Of Arrival), and A-GPS (network-assisted Global Positioning System). The system is made up of a core network and a W-CDMA radio access network (RAN) in which the radio network controller (RNC) is responsible for controlling a number of base stations to establish connections to mobile terminals. When a client terminal transmits a location request to the location system by specifying accuracy of the location of a target mobile terminal or UE (user equipment) terminal, the request is passed through the core network to the RNC, one of the positioning methods is selected according to the requested accuracy and/or the positioning capability of the target UE terminal to perform measurement and position calculation and returns a location report message to the client terminal.

Since all traffic to and from mobile terminals is concentrated on the RNC and the selection of a positioning method is a complex, time-consuming process, the processing burden is significant when the network is under heavy traffic load.

In addition, no consideration has been taken of other factors to select a positioning method, such as the environment of the target UE terminal. As a



1 result, if a target mobile user is located in a place such as underground  
2 shopping areas where GPS satellites are not observable and if the RNC selects  
3 A-GPS according to the requested accuracy, the location request results in a  
4 useless traffic, unnecessarily consuming network resources.

#### 5 SUMMARY OF THE INVENTION

6 It is therefore an object of the present invention to provide a location  
7 system and a method for operating a mobile terminal as a responsible  
8 location for selecting a positioning method.

9 According to a first aspect of the present invention, there is provided a  
10 location system comprising a mobile terminal including a plurality of location  
11 processors for performing measurement for locating the mobile terminal  
12 according to different positioning methods, a plurality of wireless nodes for  
13 establishing a wireless link to the mobile terminal, and a controlling node  
14 connected to the wireless nodes. The controlling node transmits a control  
15 message to the mobile terminal in response to a location request message  
16 from a client terminal which contains requested accuracy of location  
17 information of the mobile terminal. The requested accuracy is copied into the  
18 control message. In response to the control message, the mobile terminal  
19 selects one of the positioning methods that satisfies the requested accuracy of  
20 the control message and operates the location processor of the selected  
21 method to produce measurement data.

22 Specifically, the mobile terminal has capability information indicating  
23 positioning methods supported by the mobile terminal and selectability of  
24 the positioning methods. The controlling node receives the capability  
25 information from the mobile terminal and transmits the control message as a  
26 first control message to the mobile terminal if the capability information  
27 indicates that the mobile terminal is capable of selecting positioning methods,  
28 and a second control message to the mobile terminal if the capability  
29 information indicates that the mobile terminal is not capable of selecting  
30 positioning methods. The second control message specifies one of the

1 positioning methods supported by the mobile terminal, and  
2 wherein the mobile terminal is responsive to the second control message for  
3 operating one of the location processors whose method is specified in the  
4 second control message to producing measurement data.

5 According to a second aspect, the present invention provides a  
6 locating method by using a mobile communication network, wherein the  
7 network comprises a mobile terminal capable of performing measurement for  
8 locating the mobile terminal according to different positioning methods, a  
9 plurality of wireless nodes for establishing a wireless link to the mobile  
10 terminal, and a controlling node connected to the wireless nodes. The  
11 method comprises the steps of transmitting a control message from the  
12 controlling node to the mobile terminal in response to a location request  
13 message from a client terminal. The location request message contains  
14 requested accuracy of location information of the mobile terminal, and the  
15 control message contains a copy of the requested accuracy. At the mobile  
16 terminal, one of the positioning methods that satisfies the requested accuracy  
17 of the control message is selected and measurement is performed according  
18 to the selected method to produce measurement data.

19 According to a third aspect, the present invention provides a mobile  
20 terminal for a cellular communication network. The mobile terminal  
21 comprises control means for (a) transmitting capability information to the  
22 network, indicating positioning methods supported by the mobile terminal,  
23 (b) receiving a first control message from the network indicating that the  
24 mobile terminal is responsible for selecting positioning methods and  
25 containing accuracy of location information of the mobile terminal requested  
26 by a client terminal, (c) selecting one of the positioning methods if the  
27 requested accuracy is satisfied by at least one of the positioning methods, (d)  
28 receiving a second control message from the network specifying a positioning  
29 method, and (e) selecting the positioning method specified in the second  
30 control message; and a plurality of location processors of different

1 positioning methods, one of the location processors whose method is selected  
2 by the control means producing measurement data.

3 BRIEF DESCRIPTION OF THE DRAWINGS

4 The present invention will be described in detail further with reference  
5 to the following drawings, in which:

6 Fig. 1 is a block diagram of a location system of the present invention;

7 Fig. 2 is a block diagram illustrating details of the network nodes of the  
8 location system according to one embodiment of the present invention;

9 Figs. 3A, 3B, 3C and 3D are illustrations of the contents of control  
10 messages used in the present invention;

11 Fig. 4 is a flowchart of the operation of the radio network controller  
12 (RNC) of Fig. 2 according to one embodiment of the present invention;

13 Fig. 5 is a flowchart of the operation of the user equipment (UE)  
14 terminal of Fig. 2 associated with Fig. 4;

15 Fig. 6 is a sequence diagram of events that occur when the RNC and  
16 UE terminal operate according to the flowcharts of Figs. 4 and 5;

17 Fig. 7 is a flowchart of the operation of the RNC according to a  
18 modification of Fig. 4 when the UE terminal fails in measurement/ position  
19 calculation;

20 Fig. 8 is a flowchart of the operation of the RNC when it responds to  
21 an assistance data request message from the UE terminal;

22 Fig. 9 is a sequence diagram of events that occur when the RNC and  
23 the UE terminal operate according to the flowchart of Fig. 8;

24 Fig. 10 is a block diagram illustrating details of the network nodes of  
25 the location system when the location server is used to exchange control data  
26 direct with the UE terminal according to a location application program;

27 Fig. 11 is a flowchart of the operation of the location server of Fig. 10;

28 Fig. 12 is a flowchart of the operation of the UE terminal of Fig. 10;

29 Fig. 13 is a sequence diagram of events that occur when the location  
30 server and the UE terminal operate according to the flowcharts of Figs. 11

1 and 12;

2 Fig. 14 is a flowchart of the operation of the UE terminal when the  
3 count number of base stations and the count number of observable GPS  
4 satellites are used for selecting a positioning method;

5 Fig. 15 is a flowchart of the operation of the UE terminal when the  
6 waiting time requested by the client terminal is used for selecting a  
7 positioning method;

8 Fig. 16 is a flowchart of the operation of the UE terminal when the  
9 moving speed of the UE terminal is used for selecting a positioning method;

10 Fig. 17 is an illustration of a mapping table used by the UE terminal  
11 when operating according to Fig. 16;

12 Fig. 18 is a flowchart of the operation of the UE terminal when the  
13 distance traveled by the UE terminal is used for selecting a positioning  
14 method;

15 Fig. 19 is an illustration of a mapping table used by the UE terminal  
16 when operating according to Fig. 18;

17 Fig. 20 is a flowchart of the operation of the UE terminal according to a  
18 modification of Fig. 18;

19 Fig. 21 is a flowchart of the operation of the UE terminal when past  
20 location information records are used; and

21 Fig. 22 is an illustration of a mapping table used by the UE terminal  
22 when operating according to Fig. 21.

23 DETAILED DESCRIPTION

24 Referring now to Fig. 1, there is shown a location system constructed  
25 with basic network elements or nodes arranged in a simplified network  
26 configuration as a typical example for the description of the present  
27 invention. The system is generally comprised of an external communications  
28 network 1 such as PSTN (public switched telephone network), a core network  
29 3 and a radio access network (RAN) 4. An LCS (LoCation System) client  
30 terminal 2 of the external network 1 accesses the core network 3 when the

1 client requests location service from the system. Core network 3 includes  
2 GMLC (Gateway Mobile Location Center) 6, a MSC (Mobile Switching  
3 Center)/SGSN 8 (Serving General packet radio service Support Node)  
4 connected to the GMLC 6. MSC/SGSN 8 is normally responsible for making  
5 registration of both home and visiting mobile terminals in an associated  
6 home location database, not shown, and updates their associated serving  
7 node (MSC/SGSN) when they change their location. Radio access network 4  
8 comprises a radio network controller (RNC) 9 and a plurality of wireless base  
9 stations 10 located at respective cell-site and connected through land lines to  
10 the RNC 9. These base stations 10 are known as "nodes B" according to the  
11 3GPP terminology. RNC 9 performs location service control functions  
12 between the MSC/SGSN and each base station 10. A mobile terminal 5,  
13 known as user equipment (UE), is shown wirelessly connected to one of the  
14 base stations 10.

15 A location server 11 may be connected to the GMLC 6, as an  
16 independent network entity of the core network, to exchange control  
17 messages directly with the UE terminal 5 for position measurement and  
18 calculation by operating an application program, using the RNC and the  
19 associated base station as a message repeater.

20 Details of the network nodes of Fig. 1 are illustrated in Fig. 2, in which  
21 logical paths are used, instead of physical paths, for interconnecting various  
22 functions and for message transmission.

23 Radio network controller 9 is comprised of a controller 101, a location  
24 processors module 102, a memory 104, and an assistance data generation  
25 module 103. Base station 10 includes a field intensity detector 111 for  
26 detecting field intensities of wireless signals from mobile terminals and  
27 reports the detected field intensities to the assistance data generation module  
28 103 when requested by the RNC controller 101. Location processors module  
29 102 performs location measurement and calculation according to one of a  
30 plurality of positioning methods specified by the controller 101.

1           These positioning methods include the Cell-ID mode, the A-GPS  
2 (network assisted GPS) mode, the UE-based OTDOA (observed time  
3 difference of arrival) mode, and the UE-assisted OTDOA mode.

4           The Cell-ID mode is a method that determines the identity of a cell in  
5 which the target UE is in and the identity of the cell is used as a location of  
6 the UE terminal. The precision of this method is said to lie in the range 100  
7 meters to several kilometers. In the UE-assisted mode of OTDOA, the UE  
8 measures the difference in time of arrival of base-transmitted signals and  
9 transmits the measurement results to the network, where the RNC carries out  
10 the position calculation. In the UE-based mode, the UE makes the  
11 measurements and also carries out the position calculation and thus requires  
12 additional information (such as the position of the measured base stations)  
13 that is required for the position calculation. The precision of this method is  
14 between 50 meters and 150 meters. In the A-GPS, the UE terminal calculates  
15 the phase differences between GPS signals to determine the distances  
16 between the UE and the GPS satellites. The precision of this method is said to  
17 be 5 to 10 meters.

18           UE terminal 5 includes a network interface 120 for receiving signals  
19 from surrounding base stations and establishing a connection to the nearest  
20 base station. A field intensity detector 121, connected to the interface 120,  
21 detects the field intensities of the base-transmitted signals and provides its  
22 output to a controller 126. A moving speed detector 122, also connected to  
23 the network interface 120, measures the moving speed of the UE terminal 5.  
24 A GPS (Global Positioning System) interface 123 is provided to receive  
25 signals from GPS satellites. A GPS processor 124 is connected to the GPS  
26 interface to perform measurement and calculation on the received GPS  
27 signals and feeds its output to the controller 126. Controller 126 uses the  
28 output of the field intensity detector 121 to determine the count number of  
29 surrounding base stations which can be used for position calculation and  
30 stores this count number in a memory 125. Controller 126 uses the output of

1 the moving speed detector 122 to determine the distance travelled by the UE  
2 during a specified time interval. Further, the controller 126 uses the output of  
3 the GPS processor 124 to determine the count number of GPS satellites used  
4 in the position calculation and stores this count number into the memory 125.

5 UE terminal 5 is further provided with a location processors module  
6 127. This module performs measurement and/or position calculation  
7 according to one of the positioning methods which is selected by the UE  
8 terminal 5 or specified by the RNC 9. The information of the positioning  
9 capability of the UE terminal 5 is stored in the memory 125.

10 In addition, response time data are stored for different positioning  
11 methods to be used as a reference for comparison with a requested waiting  
12 time.

13 The UE's controller 126 exchanges various control messages with the  
14 RNC controller 101 via the base station 10.

15 When the UE terminal 5 establishes a connection to the mobile  
16 communication network, the controller 126 transmits a RRC (radio resource  
17 control) connection request (CR) message to the RNC 9 via the base station  
18 10. In response, the RNC controller 101 returns a connection setup (CS)  
19 message to the UE controller 126. The UE controller 126 establishes a  
20 connection to the RNC 9 and reads the UE's positioning capability  
21 information from the memory 125 and formulates a connection setup  
22 complete (CSC) message with the capability information and transmits it to  
23 the RNC 9.

24 As illustrated in Fig. 3A, the connection setup complete message  
25 includes a positioning method selectability field 31, a UE-based OTDOA field  
26 32 and a network assisted GPS field 33. If the UE terminal 5 is capable of  
27 selecting positioning methods, a "1" is set in the field 31. Otherwise, a "0" is  
28 set in the field 31. If the UE terminal 5 supports the UE-based OTDOA (as  
29 well as UE-assisted OTDOA), a "1" is set in the field 32. Otherwise, a "0" is  
30 set in the field 32. In the GPS field 33, if the network-based GPS is supported,



1 a "0" is set, and if the UE-based GPS is supported, a "1" is set, and if both  
2 network-based and UE-based GPS methods are supported, a "2" is set. If the  
3 network-assisted GPS method is not supported, a "3" is set in the field 33.

4 Upon receipt of the connection setup complete message from the UE  
5 terminal, the RNC 9 stores the positioning capability information contained  
6 in the message into the memory 104.

7 When the client terminal 2 desires the location information of the UE  
8 terminal, it transmits a location request (LRQ) message to the core network 3,  
9 which is passed on through the GMLC 6 to the MSC/SGSN 8 of the core  
10 network 3. In response to the client's location request message requesting the  
11 location of the target UE, the MSC/SGSN 8 transmits a location reporting  
12 control (LRC) message to the RNC 9.

13 As shown in Fig. 3B, the location reporting control message includes a  
14 horizontal accuracy code field 34, a vertical accuracy code field 35 and a  
15 response time field 36. The codes indicating the horizontal and vertical  
16 accuracy of the location information as requested by the client are set in the  
17 fields 34 and 35, respectively, and the response time (waiting time) requested  
18 by the client to receive a location report is set in the response time field 36.

19 Fig. 4 is a flowchart of the operation of the RNC' controller 101  
20 according to one embodiment of the present invention, which will be  
21 described in conjunction with a sequence diagram shown in Fig. 6. In  
22 response to a location request (LRQ) message from the client (event 601, Fig.  
23 6), the MSC/SGSN 8 formulates a location reporting control (LRC) message  
24 (event 602) and transmits the message to the RNC 9, the controller 101  
25 receives the LRC message (step 401) and proceeds to step 402 to read the  
26 horizontal and vertical accuracy codes contained in the received message  
27 (event 603, Fig. 6). At step 403, the controller 101 checks to see if the Cell-ID  
28 positioning method is satisfactory for the requested accuracy.

29 If the Cell-ID positioning method is not satisfactory for the requested  
30 accuracy, the controller 101 proceeds from step 403 to step 404 to read the

1 location capability information of the UE terminal 5 from the memory 104  
2 and determines whether the UE terminal is capable of selecting positioning  
3 methods.

4 If the UE terminal is capable of selecting a positioning method, flow  
5 proceeds from step 405 to step 406 to formulate a measurement control (MC)  
6 message. As shown in Fig. 3C, the MC message includes a positioning  
7 methods field 37, a horizontal accuracy code field 38, a vertical accuracy code  
8 field 39 and a response time field 40. In the MC message, the accuracy codes  
9 and response time data are copied from the received LRC message into the  
10 fields 38, 39 and 40 of the MC message. The MC message is then transmitted  
11 from the RNC 9 to the UE terminal 5 (step 407, event 604). If the decision at  
12 step 405 is negative, flow proceeds to step 408 to select one of the positioning  
13 methods which is supported by the UE terminal and the controller 101  
14 formulates a MC message by setting the selected method indication in its  
15 positioning methods field 37 and transmits the message (step 407).

16 If the Cell-ID method is satisfactory for the requested accuracy, flow  
17 proceeds from step 403 to step 409 for making a search for the cell in which  
18 the UE terminal 5 is currently located and recognizes its cell identity. If the  
19 UE's current cell is found (step 410), flow proceeds to step 411 to translate the  
20 cell identity to corresponding geographic location information. At step 412, a  
21 location report (LRP) message is formulated with the location information  
22 and transmitted back to the MSC/SGSN 8. If no cell is found (step 410), flow  
23 proceeds to step 413 to send an error-indicating location report message to  
24 the MSC/SGSN 8.

25 Referring to Fig. 5, the operation of the UE's controller 126 begins with  
26 the reception of a measurement control (MC) message from the RNC 9 (step  
27 501). Controller 126 proceeds to step 502 to read the positioning method data  
28 contained in the received MC message (Fig. 3C) and examines its positioning  
29 method field 37 and determines whether the UE terminal is responsible for  
30 selecting a positioning method (step 503). If the UE terminal is not

1 responsible for selecting a positioning method, flow proceeds from step 503  
2 to step 504 to perform measurement according to the positioning method  
3 specified in the positioning method field 37 of the received MC message. If  
4 the measurement is successful (step 505), the measured data is used to  
5 calculate the position of the UE terminal to produce its location information  
6 (step 506). At step 507, a measurement report (MRP) message is formulated  
7 with the location information and transmitted back to the RNC 9. If the  
8 measurement is not successful (step 505), flow proceeds to step 508 to check  
9 to see if alternative positioning methods are available. If so, the controller 126  
10 proceeds to step 511 to select one of the alternative positioning methods.

11 If no alternative methods are available, flow proceeds from step 508 to  
12 509 to send an error-indicating measurement report message to the RNC 9.  
13 Alternatively, step 509 may be executed when it is determined at step 505 that  
14 the measurement is not successful by skipping step 508.

15 If the UE terminal is responsible for selecting positioning methods  
16 (step 503), the controller 126 proceeds to step 509 to read the horizontal and  
17 vertical accuracy codes contained in the received MC message, and checks to  
18 see if the requested accuracy is satisfied by at least one of the positioning  
19 methods (step 510). If so, flow proceeds to step 511 to select one of the  
20 positioning methods (event 605).

21 Controller 126 determines, at step 512, whether assistance data is  
22 required. If not, flow returns to step 504 to perform measurement according  
23 to the positioning method selected by the UE terminal at step 511. If  
24 assistance data is required, the controller 126 sends an assistance data request  
25 (ADR) message to the RNC 9 (step 513, event 606). As shown in Fig. 3D, the  
26 ADR message includes a positioning methods field 41 and a method type  
27 field 42. In the positioning field 41, the positioning method selected by the  
28 UE terminal is indicated. Method type field 42 indicates which one of the  
29 UE-based and UE-assisted modes of the selected positioning method is  
30 selected.

1           As will be described in detail later, the RNC 9 responds to the ADR  
2 message by producing assistance data and returning an assistance data  
3 delivery (ADD) message to the UE terminal (event 607).

4           When the UE controller 126 receives the ADD message from the RNC  
5 9 (step 514), it returns to measurement step 504 to perform measurement  
6 using the additional assistance data (event 608). If the measurement is  
7 successful (step 505), position calculation is performed on the measured data  
8 (step 506, event 609). A measurement report (MRP) message is then  
9 formulated with the calculated position data and transmitted to the  
10 MSC/SGSN 8 (step 507, event 610).

11          Returning to Fig. 4, the RNC controller 101 receives the MRP message  
12 from the UE terminal at step 421. Controller 101 checks to see the MRP  
13 message contains a measured or calculated result, or an error indication. If  
14 the MRP message contains a measured result, flow proceeds to step 423 to  
15 calculate the position of the UE terminal using the measured result and  
16 proceeds to step 412 to send a location report (LRP) message to the  
17 MSC/SGSN 8 (event 611). If the MRP message contains a calculated result,  
18 flow proceeds to step 412. If the MRP message is an error-indicating  
19 message, the controller proceeds to step 413 to send an error report to the  
20 MSC/SGSN. Location report message from the RNC 9 is repeated by the  
21 MSC/SGSN to the client terminal (event 612).

22          A modified embodiment of the RNC 9 is illustrated in Fig. 7. When  
23 the UE terminal fails in measuring signals according to OTDOA or A-GPS  
24 method and an error-indicating LRP message is returned to the RNC 9, the  
25 RNC controller 101 recognizes this fact at decision step 701 and proceeds to  
26 cell-search step 702 to perform a Cell-ID positioning method. Although the  
27 client is informed of less accurate location information than it requested, it is  
28 better than the error-reporting message.

29          Fig. 8 shows details of the operation of RNC 9 when delivering  
30 assistance data to the UE terminal in response to its AD request message (step

1 801). At step 802, the positioning method specified in the received ADR  
2 message is read. RNC controller 101 determines whether OTDOA method is  
3 specified. If so, flow proceeds to step 804 to read data from the method type  
4 field of the message. If the UE-based OTDOA is specified (step 805), the RNC  
5 controller 101 transmits a request message known as "common measurement  
6 initiation (CMI)" message to a plurality of base stations 10. In each base  
7 station, the measurement module 111 measures the time of transmission of its  
8 cell-site signal to the UE terminal and notifies the RNC 9 of the transmission  
9 time. Each base station encapsulates the measurement result in a CMI  
10 message and transmits the message to the RNC 9. RNC controller 101  
11 receives such CMI response messages from the base stations 10 (step 807) and  
12 formulates UE-based OTDOA assistance data with the measured cell-site  
13 transmission times (step 808) and encapsulates the UE-based OTDOA  
14 assistance data in an assistance data delivery (ADD) message and transmits  
15 the message to the UE terminal 5 (step 809).

16 If the decision at step 805 is negative, the RNC controller determines  
17 that UE-assisted mode is selected, and proceeds to step 810 to transmit a UE-  
18 assisted OTDOA assistance data message to the UE terminal, containing a  
19 number of codes specifying base stations so that the UE terminal measures  
20 the time difference of arrivals from the specified base stations. At step 811,  
21 the RNC controller 101 transmits a CMI message to base stations 10 and  
22 receives CMI response messages from the base stations (step 812). The  
23 transmission time data of the base stations contained in the received CMI  
24 messages are stored in the memory 104 (step 813) to perform the position  
25 calculation on the measurement results which will be supplied from the UE  
26 terminal 5.

27 If the decision at step 803 is negative, the RNC controller determines  
28 that GPS mode is selected, and proceeds to step 814 to check to see if the UE-  
29 based A-GPS method is specified in the received message (step 815). If this is  
30 the case, the RNC controller proceeds to step 816 to formulate UE-based A-

1 GPS assistance data and encapsulates it in an assistance data delivery  
2 message and transmits the message to the UE terminal. If the decision at step  
3 815 is negative, it is determined that UE-assisted A-GPS method is specified  
4 and flow proceeds to step 817 to formulate UE-assisted A-GPS assistance  
5 data, which is then encapsulated in an assistance data delivery message and  
6 transmitted to the UE terminal (step 809).

7 If the decision at step 814 is negative, flow proceeds to decision step  
8 818 to determine whether the GPS method is of the UE-based or UE-assisted  
9 mode. If the GPS method is UE-based, the RNC controller proceeds to step  
10 819 to transmit CMI messages to a number of base stations to receive their  
11 CMI response messages (step 820) and formulates UE-based OTDOA and  
12 UE-based A-GPS assistance data with the CMI response messages at step 821,  
13 which is then encapsulated in an assistance data delivery message and  
14 transmitted to the UE terminal (step 809). If the GPS method is UE-assisted,  
15 the RNC controller proceeds from step 818 to step 822 to formulate UE-  
16 assisted OTDOA and UE-assisted A-GPS assistance data, which is then  
17 encapsulated in an assistance data delivery message and transmitted to the  
18 UE terminal (step 809).

19 The overall operation of the system according to the flowchart of Fig. 8  
20 is illustrated in the sequence diagram of Fig. 9. When the RNC receives an  
21 assistance data request message (event 606), it sends CMI messages (event  
22 901) to base stations (only one base station is illustrated for simplicity). Each  
23 base station performs the measurement of the time of its transmission to the  
24 UE terminal and returns a CMI response message to the RNC (event 902). In  
25 response, the RNC transmits an assistance data delivery message to the UE  
26 terminal (event 904). The UE terminal responds to the ADD message by  
27 performing measurement (event 905). If the selected positioning method is  
28 other than UE-assisted OTDOA, the UE terminal provides the position  
29 calculation (event 906) and returns a measurement report message to the  
30 RNC (event 907), which then returns a location report message to the

1 MSC/SGSN (event 908). If the selected positioning method is UE-assisted  
2 OTDOA, the UE terminal does not perform the position calculation 906.  
3 Instead, the RNC performs the position calculation (event 909) in response to  
4 receipt of the measurement report message.

5 In a modified embodiment shown in Fig. 10, a logical two-way  
6 communication path is established between the location server 11 and the UE  
7 terminal 5 to exchange control messages, using the RNC and the UE-  
8 communing base station as physical repeating mediums. Location server 11  
9 includes a controller 131, an assistance data generation module 132 and a  
10 memory 133 for storing a location application program. UE terminal 5  
11 additionally includes a memory 128 for storing a location application  
12 program. Controller 126 operates according to the location application  
13 program and interacts with the server controller 131 running on its location  
14 application program.

15 The operation of the location server 11 proceeds according to the  
16 flowchart of Fig. 11. When the location server 11 receives a location request  
17 message from the client terminal (step 1101), the server controller 131 initiates  
18 its location application program (step 1102) to establish a connection to the  
19 UE controller 126 and transmits an enquiry message to the UE controller 126  
20 (step 1103) to receive a reply message from the target UE (step 1104). The  
21 reply message contains the positioning capabilities of the UE terminal 5.  
22 Server controller 131 examines the reply message and determines whether  
23 the UE terminal is capable of selecting positioning methods. If the UE  
24 terminal is capable of selecting positioning methods, flow proceeds to step  
25 1106 to transmit a location request message to the target UE terminal to  
26 receive a location report message from the UE terminal (step 1107). Server  
27 controller 131 notifies the client terminal of the location result (step 1108) and  
28 terminates the location application program (step 1109).

29 If the decision at step 1105 is negative, flow proceeds to step 1110 to  
30 read the horizontal and vertical accuracy codes contained in the location

1 request message received from the client terminal. At step 1111, the server  
2 controller 131 checks to see if the requested accuracy is satisfied by at least  
3 one positioning method. If so, one of the positioning methods is selected at  
4 step 1112 and flow proceeds to step 1106 to transmit a location request  
5 message to the UE terminal, requesting it to perform measurement and/or  
6 position calculation according to the selected positioning method. If the  
7 requested accuracy is not satisfied by any of the positioning methods, flow  
8 branches out from step 1111 to step 1108 to notify the client of this fact.

9       If an assistance data request message is received from the UE terminal  
10 (step 1113), the server controller 131 proceeds to step 1114 to determine if  
11 assistance from base stations is required. If no assistance from base stations is  
12 required, flow proceeds to step 1115 to formulate an assistance data delivery  
13 message with its own assistance data and transmits the message to the UE  
14 terminal and terminates the location application program (1109). If  
15 assistance from base stations is required, flow proceeds from step 1114 to step  
16 1116 to transmit a measurement request message to a number of base stations  
17 and receive their measurement results (indicating the time of their signal  
18 transmission to the UE terminal) at step 1117. If the measurements are  
19 successful (step 1118), the server controller proceeds to step 1115 to formulate  
20 an assistance data delivery message with the measurement results and  
21 transmits the message to the UE terminal. If the measurements are not  
22 successful, flow proceeds from step 1118 to step 1119 to notify the UE  
23 terminal of the unavailability of assistance from base stations and terminates  
24 the location application program (step 1109).

25       The operation of the UE terminal in response to a message from the  
26 location server 11 proceeds according to the flowchart of Fig. 12. Upon  
27 receipt of a message from the server 11 (step 1201), the UE controller 126  
28 proceeds to step 1202 to initiate the location application program, and  
29 determines the type of the received message. If the received message is an  
30 enquiry message, flow proceeds to step 1204 to transmit its positioning



1 capabilities to the server 11 and terminates the location application program  
2 (step 1205).

3       If the received message is a location request, flow proceeds from step  
4 1203 to step 1206 to determine if the UE terminal is responsible for selecting  
5 positioning methods. If so, flow proceeds to step 1207 to read the horizontal  
6 and vertical accuracy codes contained in the received location request  
7 message and then checks to see if the requested accuracy is satisfied by at  
8 least one positioning method. If the requested accuracy is satisfied by at least  
9 one positioning method, one of the positioning method is selected (step 1209).  
10 UE controller 126 then determines if assistance data is required for the  
11 selected positioning method (step 1210). If so, the UE controller transmits an  
12 assistance data request message to the location server 11 (step 1211) and  
13 proceeds to program termination step 1205.

14       If the decision at step 1208 is negative, flow proceeds to step 1212 to  
15 determine if alternative positioning methods are available. If so, flow  
16 proceeds to method selection step 1213. Otherwise, flow proceeds to step  
17 1210 to send an error message to the location server 11. Note that decision  
18 step 1212 may be dispensed with depending on applications.

19       If the decision at step 1206 is negative, flow proceeds to step 1214 to  
20 read the positioning method specified in the received location request  
21 message and proceeds to decision step 1210.

22       If the decision at step 1210 indicates that no assistance data is required,  
23 flow proceeds to step 1215 to perform location measurement according to the  
24 positioning method selected by the UE terminal at step 1209. If the  
25 measurement is successful (step 1216), the UE controller proceeds to step  
26 1217 to perform the position calculation and transmits the location result to  
27 the location server 11 (step 1218) and terminates the application program  
28 (step 1205). If the measurement is unsuccessful, step 1217 is skipped and an  
29 error-indicating location result message is sent to the location server (1218).

30       If the decision at step 1203 indicates that the message received from

1 the location server is assistance data, flow proceeds to step 1215 to perform  
2 the location measurement.

3 The overall operation of the location system according to the  
4 flowcharts of Figs 11 and 12 is shown in the sequence diagram of Fig. 13.  
5 When the location server receives a location request message from the client  
6 (event 1301), it initiates the application program (event 1302) to establish a  
7 virtual connection to the UE terminal and transmits a capability enquiry  
8 message to the UE terminal over the established connection (event 1303). The  
9 UE terminal responds to the enquiry message by initiating its application  
10 program (event 1304) and transmitting a capability reply message to the  
11 location server (event 1305). The location server transmits a copy of the  
12 client's location request message to the UE terminal (event 1306). If the  
13 location request message indicates that the UE terminal is responsible for  
14 selecting a positioning method, a positioning method selection is performed  
15 (event 1307), and if assistance data is required, the UE terminal transmits an  
16 assistance data request message to the location server (event 1308) and  
17 receives an assistance data delivery message from the location server (event  
18 1309). The UE terminal performs measurement (event 1310) and position  
19 calculation (event 1311) and transmits a location report message to the  
20 location server (event 1312) and terminates its application program (event  
21 1313). The location server repeats the received location report message to the  
22 client (event 1314) and terminates its application program (event 1315).

23 In the previous embodiments, horizontal and vertical accuracy codes  
24 requested by the client are used as a decision threshold for allowing the UE  
25 terminal to select a positioning method.

26 The following are modified embodiments of the operation of the UE  
27 terminal of Fig. 5 and are illustrated in Figs 14, 15, 16, 18, 20 and 21, in which  
28 parts corresponding to those of Fig. 5 are marked with the same numerals as  
29 those in Fig. 5 and the description thereof is omitted for simplicity.

30 In the following modifications, additional decision thresholds are

1 used. These include the count number of observable GPS satellites and the  
2 count number of nearby base stations, the response time (waiting time  
3 requested by the client to receive a location report), the moving speed of the  
4 UE terminal and the distance traveled by the UE terminal. A further decision  
5 threshold is whether the UE terminal has a

6 In Fig. 14, when the UE controller 126 retrieves the horizontal and  
7 vertical accuracy codes from the MC (measurement control) message received  
8 from the RNC 9 (step 509), it proceeds to decision step 1401 to check to see if  
9 the requested accuracy is satisfied by the OTDOA method. If the decision at  
10 step 1401 indicates that the requested accuracy is satisfied by the OTDOA  
11 method, flow proceeds to step 1402 to read the base-station count number (B)  
12 from the memory 125 and compares it with a decision threshold (step 1403).  
13 If the count number B is higher than the decision threshold, the UE controller  
14 selects the OTDOA method at step 1404 and proceeds to location  
15 measurement step 504.

16 If the decision at step 1403 indicates that the base-station count  
17 number B is lower than the threshold, the UE controller reads the GPS-  
18 satellite count number (S) from the memory 125 (step 1405) and compares it  
19 with a decision threshold (step 1406). If the satellite count number S is higher  
20 than the decision threshold, the UE controller selects the A-GPS method and  
21 proceeds to location measurement step 504. If the decision is negative at step  
22 1406, flow proceeds to step 508 to send an error-indicating measurement  
23 report message to the RNC 9.

24 If the requested accuracy is not satisfied by the OTDOA method (step  
25 1401), the UE controller proceeds to step 1408 to read the GPS-satellite count  
26 number S from the memory 125 and compares it with a decision threshold  
27 (step 1409). If the satellite count number S is higher than the decision  
28 threshold, the UE controller proceeds to step 1407 to select the A-GPS method  
29 and proceeds to location measurement step 504. If the comparison decision at  
30 step 1409 is negative, the UE controller proceeds to step 1410 to read the base-

1 station count number B from the memory 125 and compares it with a decision  
2 threshold (step 1411). If the count number B is higher than the threshold, the  
3 UE controller selects the OTDOA method (step 1404) and proceeds to location  
4 measurement step 504. If the decision at step 1411 is negative, flow proceeds  
5 to step 508 to return an error-indicating measurement report to the RNC.

6 In Fig. 15, when the UE controller 126 determines that it is responsible  
7 for making a selection from positioning methods (step 503), it reads the  
8 horizontal and vertical accuracy codes and the requested response time "W"  
9 (waiting time) from the MC (measurement control) message received from  
10 the RNC 9 (step 1501), and proceeds to decision step 1502 to check to see if  
11 the requested horizontal and vertical accuracy is satisfied by the OTDOA  
12 method. If the decision at step 1502 indicates that the requested accuracy is  
13 satisfied by the OTDOA method, flow proceeds to step 1503 to read the  
14 response time ( $T_O$ ) required for the OTDOA method from the memory 125  
15 and compares it with the requested waiting time (step 1504). If the response  
16 time  $T_O$  is equal to or smaller than the requested waiting time W, the UE  
17 controller selects the OTDOA method at step 1505 and proceeds to location  
18 measurement step 504.

19 If the decision at step 1504 indicates that the response time  $T_O$  is equal  
20 to or smaller than the requested waiting time W, the UE controller reads the  
21 response time  $T_G$  for the A-GPS method from the memory 125 (step 1506)  
22 and compares it with the requested waiting time W (step 1507). If  $T_G$  is  
23 equal to or smaller than W, the UE controller selects the A-GPS method (step  
24 1508) and proceeds to location measurement step 504. If  $T_G$  is greater than  
25 W, the response times  $T_O$  and  $T_G$  are compared with each other at step 1509.  
26 If  $T_O$  is smaller than  $T_G$ , the OTDOA method is selected (step 1505). If  $T_O$  is  
27 greater than  $T_G$ , the A-GPS method is selected (step 1508).

28 In Fig. 16, when the UE terminal determines that it is responsible for  
29 making a method selection (step 503), it proceeds to step 1601 to determine  
30 the UE's moving speed. In this embodiment, various moving speed values

1 are mapped to usable positioning methods in a table 1701 as shown in Fig. 17.

2 At step 1602, the UE controller makes a search through the speed-  
3 method mapping table 1701 for detecting one or more methods  
4 corresponding to the determined moving speed. If such positioning methods  
5 are detected (step 1603), the UE controller selects one of the detected methods  
6 (step 1604) and proceeds to the location measurement step 504. If no  
7 corresponding method is found in the mapping table 1701 (step 1603), flow  
8 proceeds to step 508 to transmit an error-indicating measurement report to  
9 the RNC.

10 In Fig. 18, when the UE terminal determines that it is responsible for  
11 making a method selection (step 503), it proceeds to step 1801 to determine  
12 the UE's moving speed. In this embodiment, different positioning methods  
13 are mapped to their required response time values in a method-response  
14 table 1901 as shown in Fig. 19.

15 At step 1802, the UE controller reads all response time values from the  
16 mapping table 1901 and proceeds to step 1803 to use all these response time  
17 values and the determined moving speed of the UE terminal for estimating  
18 distances traveled by the UE for the respective positioning methods. At step  
19 1804, the estimated distances are compared with the requested distance (i.e.,  
20 the horizontal and vertical accuracy) and one or more methods are detected  
21 whose estimated distances are equal to smaller than the requested distance.  
22 If such methods are detected (step 1805), the UE controller selects one of these  
23 methods (step 1806) and proceeds to the location measurement step 504. If  
24 no method is detected, flow proceeds from step 1805 to step 508 to transmit  
25 an error-indicating measurement report to the RNC.

26 Instead of transmitting the error-indicating measurement report to the  
27 RNC, the UE terminal may includes steps 2001 and 2002 as shown in Fig. 20.  
28 When the UE controller determines, at step 1805, that there is no positioning  
29 method that satisfies the requested distance, it proceeds to step 2001 to  
30 compare the estimated distance of each positioning method to the requested

1 distance and selects greater of the two as a new value of distance accuracy of  
2 the positioning method. At step 2002, the UE controller compares all new  
3 values of accuracy to each other and selects a positioning method whose new  
4 accuracy value is highest, and then proceeds to the location measurement  
5 step 504.

6 In Fig. 21, the UE terminal uses a last known location info table 2201,  
7 shown in Fig. 22. In this table, previous location information of the UE  
8 terminal are mapped to their observed times of day.

9 When the UE terminal determines that it is responsible for making a  
10 method selection (step 503), it proceeds to step 2101 to make a search through  
11 the last known location info table 2201 for detecting records whose times of  
12 day indicate that they are newer than a specified past time point. If such  
13 previous location information is detected (step 2102), the UE terminal reads  
14 the most recent location information from the table 2201 (step 2103) and  
15 proceeds to step 507 to transmit a measurement report message to the RNC 9,  
16 containing the most recent location information. If the UE terminal fails to  
17 find such past records, it proceeds to one of steps 1401, 1501, 1601 or 1801.